

Problem set 2 ... Examples taken from (1)
Van Wylen & Sonntag, 3rd Ed, pp. 425-427
and pp. 426-427 (Recommended book as a reference)

2000 ft³ @ 14.7 lbf/in², 90F, $\phi = 0.70$
calculate: humidity ratio, dew point, mass of air
and mass of vapor.

$$\phi = 0.70 = \frac{P_v}{P_g}$$

$P_g \leftarrow P_{\text{sat}} @ 90F$ from steam tables

$$P_v = 0.70 (0.6988) = 0.4892 \text{ lbf/in}^2$$

Again from steam tables for saturated steam
pressure table, the dew point is the saturation
temperature corresponding to this pressure $\approx 78.9F$

$$P_a = P - P_v = 14.7 - 0.49 = 14.21 \text{ lbf/in}^2$$

~~Humidity ratio~~ $w = 0.622 (P_v / P_a) = 0.02135$

$$\text{Mass of air } m_a = (P_a V / R_a T) = (14.21 * 144 * 2000) / 53.34 * 55.15$$
$$= 139.6 \text{ lbm}$$

Mass of vapor can be determined from

$$w = m_v / m_a \quad m_v = w m_a = 0.02135 (139.6)$$
$$= 2.98 \text{ lbm}$$

Now if the mixture is cooled to 40F how
much water vapor is condensed?

At the final temp of 40F, the mixture is in
a saturated state (as 40F is below the dew point)

(2)

$$P_{v_2} = P_{g_2} \quad P_{a_2} = P - P_{v_2}$$

$$\omega_2 = 0.622 (P_{v_2} / P_{a_2})$$

$$\text{Mass of vapor condensed} = m_a (\omega_1 - \omega_2)$$

(Note, mass of air is not changing, and $P_{v_2} = P_{g_2}$ when $P_{g_2} = P_{\text{sat}} @ 40^\circ\text{F}$)

$$P_{v_2} = 0.1217 \text{ lbf/in}^2 \quad P_{g_2} = 14.7 - P_{v_2} = 14.58$$

$$\omega_2 = 0.622 (0.1217 / 14.58) = 0.00520$$

Mass of vapor condensed

$$= m_a (\omega_1 - \omega_2) = 139.6 (0.02135 - 0.0052)$$

$$= 2.25 \text{ lb}_m$$

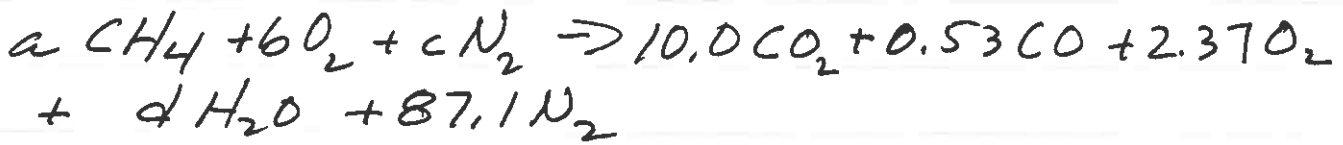
3

Methane CH_4 is burned with atmospheric air. Dry basis products yield

$$\text{CO}_2 = 10\% \quad \text{O}_2 = 2.3\% \quad \text{CO} = 0.53\% \quad \text{N}_2 = 87.1\%$$

Calculate A/F ratio and % theoretical air.

First write generalized combustion equation in the form



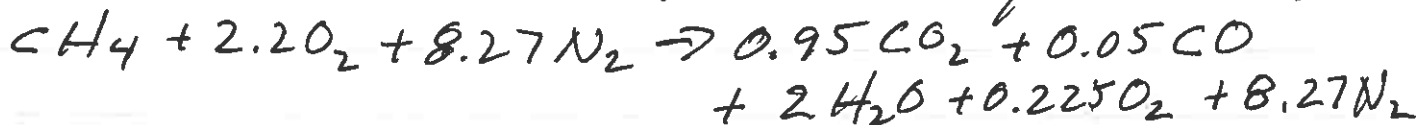
Note that we assume for this analysis that we will build a one-step reaction based on dry product yield... of course we need to determine how much H_2O is present to write the combustion equation

For nitrogen: No oxides of NO so $c = 87.1$

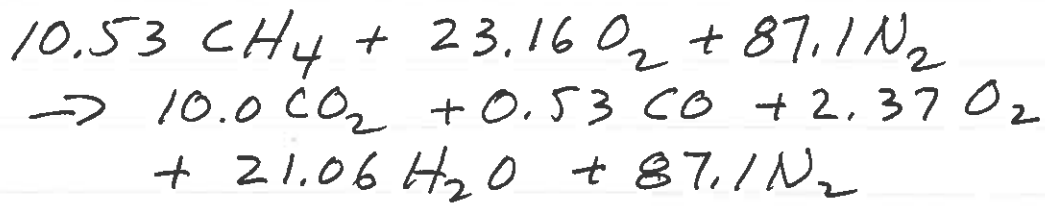
We know that the ratio of N_2/O_2 in the air is about $79/21 = 3.76$ so $c/b = 3.76$
 $b = 23.16$

From the carbon balance $a = 10.0 + 0.53 = 10.53$

~~Therefore~~ We can now write the ^{normalized} combustion equation (by \uparrow)

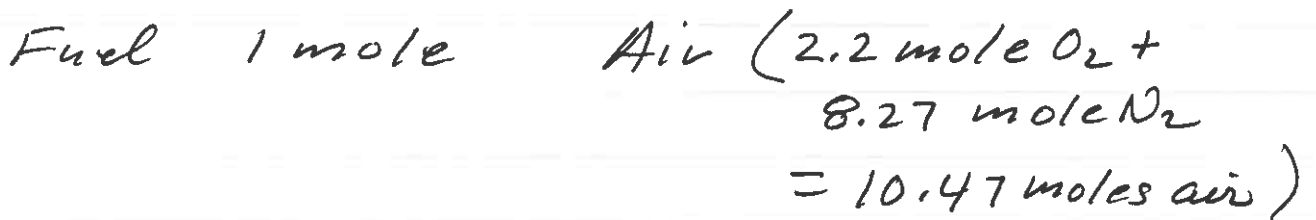


(4)



(This is the equation which we divided by 10.53 to get the combustion equation base on 1 mole of fuel)

Air-Fuel ratio on a mole basis is



ON A MASS BASIS

$$AF = (10.47 \times 28.97) / 16.0 = 18.97 \frac{\text{kg air}}{\text{kg fuel}}$$

Theoretical A/F ratio ... First write comb. equation for theoretical air

$$\text{CH}_4 + 2\text{O}_2 + 2(3.76)\text{N}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 7.52\text{N}_2 \\ (A/F)_{\text{theoretical}} = (2 + 7.52)(28.97) / 16 = 17.23 \frac{\text{kg air}}{\text{kg fuel}}$$

$$\therefore \% \text{ Theoretical air is } = \frac{18.97}{17.23} = 110\%$$